A Method for Assembling Carbon Nanotubes and Microprobe and an Apparatus Thereof

1. FIELD OF THE INVENTION:

[0001] The present invention relates to a method and an apparatus for assembling carbon nanotubes and microprobes, and more particularly, to a method and an apparatus for assembling carbon nanotubes and microprobes capable of employing the principles of Electrophoresis/Dielectrophoresis to drive the carbon nanotubes self-assembling the microprobe under an electric field.

2. BACKGROUND OF THE INVENTION:

[0002] Carbon nanotubes are single-layered/multilayered tubular carbon molecules that have properties that make them potentially useful in nanotechnology. They exhibit unusual strength and unique electrical properties, and are extremely efficient conductors of heat A nanotube is a structure similar to a fullerene, only the carbon atoms are rolled into a cylinder instead of a sphere; each end is capped with half a fullerene molecule. They are only several nanometers wide, and their length can be millions of times greater than their width, that is, several micrometers long. Carbon nanotubes have many structures, differing in length, thickness, type of spiral, and number of layers. Although they are formed from essentially the same graphite sheet, their electrical characteristics differ depending on these variations, acting either as metals or semiconductors. Carbon nanotubes are expected to become a key material in ultrafine devices of the future, because of their unique electrical characteristics, and their extraordinarily fine structure on a nanometer scale. Other merits offered by carbon nanotubes are light weight, extremely high mechanical strength (they have larger tensile strength than steel), their ability to withstand extreme heat of 2000°C in the absence of oxygen, and the fact that they emit electrons efficiently when subjected to electrical field. Currently, research is being conducted throughout the world targeting the

application of carbon nanotubes as materials for use in photoelectric elements, electronic elements, biochemistry medication, fuel cell, etc. Moreover, the high tensile strength, semi-conductivity and flexibility features thereof can be applied to a microprobe or a microelectrode of nanometer level. However, due to the tiny diameter of the carbon nanotubes, it is difficult to assembly a carbon nanotube to a microprobe.

[0003] While assembling a carbon nanotube with a microprobe, the conventional method is by adopting a chemical vapor deposition (CVD) process along with a catalyst deposition technique for growing the carbon nanotube at the place adhered with the catalyst, such as: plasma enhanced chemical vapor deposition, normal atmospheric temperature chemical vapor deposition, arc discharge, etc. However, these processes must be performed in a vacuum environment (50~400Torr) or under a very high temperature. Even a low temperature CVD will require at least 450~500°C and can only be used for multi-walled carbon nanotube (MWNTs). On the other hand, a high temperature of 1000~1200°C is needed for single-walled carbon nanotubes (SWNTs). Such conventional techniques will have difficulties when depositing carbon nanotubes on a large-scale substrate under low temperature. Furthermore, the catalyst is usually made of materials such as iron, nickel, or molybdenum, etc., in nanometer-sized powder which are not only expensive, but also will generate by-products like crystal or non-crystal carbides and residual catalyst during the process of carbon nanotube deposition. Therefore, an additional purification processes will be needed and the difficulty of the whole process also increase. The present invention provides a method for driving the carbon nanotubes self-assembling the microprobe under an electric field for overcoming the obstacle of assembling a nano-sized matter with a much larger structure.

SUMMARY OF THE INVENTION

[0004] The primary object of the invention is to provide a method for assembling a carbon nanotube and a microprobe under normal atmospheric temperature and pressure.

[0005] Another object of the invention is to provide a method for assembling a carbon nanotube and a microprobe capable of employing the principles of Electrophoresis/Dielectrophoresis to drive the carbon nanotubes attaching itself on the tip of a microprobe under a high electric field.

[0006] Yet another object of the invention is to provide a composite by assembling carbon nanotubes and a microprobe and the carbon nanotubes being attached to the tip of the microprobe in parallel to the direction of an electric field.

[0007] Another object of the invention is to provide an apparatus for assembling a carbon nanotube and a microprobe capable of performing the process of driving the carbon nanotubes to attach itself on the tip of a microprobe under a high electric field.

[0008] In order to achieve the aforementioned objectives, the method for assembling carbon nanotubes and microprobe of the invention comprises the following steps: forming at least one microprobe, the microprobe being covered by a conductive layer; exposing the microprobe to a solution having carbon nanotubes spreading therein, the solution being furnished with an electrode; applying a predetermined voltage between the conductive layer and the electrode for making at least one carbon nanotube to move and attach onto the top of the microprobe.

[0009] Following drawings are cooperated to describe the detailed structure and its connective relationship according to the invention for facilitating your esteemed members of reviewing committee in understanding the characteristics and the objectives of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a schematic diagram showing a system for assembling carbon nanotubes and microprobes by electrophoresis (or dielectrophoresis) effect; and

[0011] Fig. 2A to 2E are flow charts showing the process of making a substrate with microprobes.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012] The invention utilizing the electrophoresis (or dielectrophoresis) effect to assembling carbon nanotubes and a microprobe under normal atmospheric temperature and pressure.

[0013] Please refer to Fig. 1, which is a schematic diagram showing an apparatus for assembling carbon nanotubes and microprobes by electrophoresis (or dielectrophoresis) effect.

[0014] As shown in Fig. 1, a silicon substrate 11 with at least one microprobe 12 (four probes 12 are provided in Fig. 1 as example) formed thereon by semiconductor processing is provided. A conductive layer 13 is formed and covers the surface of the substrate 11 and the microprobe 12. The conductive layer 13 can be made of materials such as gold, copper, aluminum and other metals or alloys, and it is preferred to form such conductive layer by electroplating or film deposition. In addition, a non-conductive layer 14 is formed and covering the conductive layer 13. Although a photoresist is selected as the non-conductive layer 14 for the present preferred embodiment, other non-conductive material can be used as the non-conductive layer 14 also. The non-conductive layer 14 covers a predetermined area of the conductive layer 13 such that the portion of the conductive layer covering the tip 121 of the microprobe 12 is not covered by the non-conductive material 14 and is exposed.

[0015] The substrate 11 along with the microprobe 12, the conductive layer 13 and the non-conductive layer 14 are placed in a container having a solution 20 therein, such as a reaction tank, and a plurality of carbon nanotubes 21 is suspended in the solution 20. An electrode 31 is disposed in a position separated from the substrate 11 by a predetermined distance in the solution 20. The conductive layer 13 and the electrode 31 are connected respectively to the positive and negative of a DC power supply 45 providing a preset DC voltage via conductive grease 41, 42. Since only the portion of the conductive layer 12 covering the tip 121 of the microprobe 12 is exposed to the solution 20, the electrode 31 has a much larger area exposed to the solution 20 than that of the microprobe 12.

Therefore, an electric field concentration will occur at the tip 121 of the microprobe 12. Under the circumstance, most of the carbon nanotubes 21 in the solution 20 will move toward the tip 121 of the microprobe 12 by electrophoresis (or dielectrophoresis) effect, in addition, at the tip of the microprobe, the carbon nanotubes driven by the electric field are oriented longitudinally parallel to the electric field which is aligned with the extending direction of the microprobe 12, and further are attached to the tip 121 of the microprobe 12 by Van der Waal's force.

[0016] In a preferred embodiment, the solution 20 includes an anionic surfactant, such as Sodium dodecyl sulfate (SDS) or other surfactant, for attaching a layer of negative charges onto the surface of the carbon nanotubes 21. The conductive layer 13 is connected to the positive of the DC power supply 45 and the electrode 31 is connected to the negative of the DC power supply 45 (as shown in Fig. 1). Thus, the negative-charged carbon nanotubes 21 will move toward the tip 121 of the microprobe 12 (positive-charged) and attached to the tip 121 of the microprobe 12 by Van der Waal force. This is called electrophoresis (EP). The mobility of the carbon nanotubes 21 depends on the molecular weight thereof and is irrelevant to the charge born in the molecule.

[0017] In another preferred embodiment, the solution 20 is un-charged, such as isopropyl alcohol or other organic solution. Since the carbon nanotube 21 itself is un-charged, it will not actively move toward any electrode. However, as the conductive layer 13 exposed to the solution 20 is only at the tip 121 of the microprobe 12, the area thereof exposed to the solution 20 is far small than that of the electrode 31. Therefore, the electric field will concentrate and intensify in the vicinity of the tip 121 of the microprobe 12 that enables the happening of a non-uniform electric intensity distribution. Under the influence of the inhomogeneous electric field, the un-charged carbon nanotubes 21 are polarized and thus induced to move sideway, that is, a dipole moment is being generated on the surface of a particle due to the polarization effect induced by an electric field. In this regard, even both the isopropyl alcohol and the carbon nanotubes 21 are uncharged, the carbon nanotubes 21 will be affected by the inhomogeneous electric field and be driven to move toward the

position with higher electric field density, and eventually are attached to that position The above phenomenon is referred as dielectrophoresis.

[0018] In this preferred embodiment, the apparatus of the present invention can further comprise an ultrasonic device 46 for providing ultrasonic oscillation to the solution 20 so as to prevent the carbon nanotubes 21 from gathering together and enable the carbon nanotubes 21 to be uniformly dispersed and suspended in the solution 21.

[0019] Fig. 2A to Fig. 2E shows a processing step of the substrate 11 with microprobes 12 of Fig. 1 according to a preferred embodiment of the present invention.

[0020] First, as seen in Fig. 2A, a silicon nitride layer 52 and a mask layer 53 (e.g. a photoresist) are formed successively on the silicon substrate 51 (e.g. a silicon wafer). A photolithography and development - is applied to form several openings 531 in a predetermined position of the mask layer 53 to expose the portion of the silicon nitride layer 52 defined by the openings 531.

[0021] Following, as shown in Fig. 2B, the device of Fig. 2A is processed by reactive ion etching (RIE) and uses the substrate 51 as the end of the etching process, such that the exposed portion of the silicon nitride layer 52 defined by the openings 531 is development, and then the mask layer 53 is removed from the substrate to leave only several silicon nitride columns 521 disposed on the substrate.

[0022] Next, as shown in Fig. 2C, several tapered silicon nitride probe 522 are formed on the substrate 51 by applying anisotropic etching on the silicon nitride columns 521 .

[0023] Next, as shown in Fig. 2D, a conductive layer 54 (such as gold, copper, aluminum, nickel or other metals or alloys) is formed on the substrate 51 and probe 522 by electroplating, sputtering, physical vapor deposition, chemical vapor deposition or other methods. In the preferred embodiment, the conductive layer 54 covers the entire substrate 51 and probe 522. However, in other embodiments, the conductive layer 54 covers at least the tip of the probe 522.

[0024] Finally, as shown in Fig. 2E, a non-conductive layer 55 is formed on a predetermined area of the conductive layer 54 in a way that only the potion of the conductive layer 541 covering the tip of the probe 522 is exposed. In the preferred embodiment, the non-conductive layer 55 can be a photoresist, other non-conductive film or polymer material. The formation is, first, covering the entire conductive layer 54 with the photoresist, and then a predetermined thickness of the photoresist is etched using RIE to expose only the tip of the probe 522. Thus, the substrate with probe of Fig. 1 is accomplished.

[0025] Although, the material of the microprobe used in Figs. 2A to 2E is silicon nitride (SiN4), other materials, such as silicon oxide, metal or polymer can also be used for forming the probe on the substrate.

[0026] While the preferred embodiment of the invention has been set forth for the purpose of disclosure, modifications of the disclosed embodiment of the invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the spirit and scope of the invention.